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Report No. 05-01

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Report No. 05-01, supported by the Office of Naval Research, Arlington, VA, and the Marine Corps Warfighting Laboratory under Work Unit No. 63706N.M0095.60332. The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, or the U.S. Government. Approved for public release; distribution is unlimited. This research has been conducted in compliance with all applicable federal regulations governing the protection of human subjects in research.

Abstract

This investigation examined the wounds incurred by 279 U.S. Navy–Marine personnel (97% Marines and 3% Sailors) identified as wounded in action during Operation Iraqi Freedom from March 23 through April 30, 2003. The goal was to assess the potential impact of each causative agent by comparing the differences in anatomical locations, types of injuries caused, and the medical specialists needed to treat the casualties. The overall average number of diagnoses per patient was 2.2, and the overall average number of anatomical locations was 1.6. The causative agents were classified into 7 major categories: small arms, explosive munitions, motor vehicle accidents, falls, weaponry accidents, and other/unknown. Explosive munitions and small arms accounted for approximately 3 out of 4 combat-related injuries. Upper and lower extremities accounted for approximately 70% of all injuries, a percentage consistent for battlefield injuries since World War II.

Introduction

The development of the Navy–Marine Corps Combat Trauma Registry (CTR) has provided an excellent opportunity to assess the wounding patterns evidenced against US Marines and Sailors during Operation Iraqi Freedom (OIF). The CTR is a data warehouse composed of data sets describing the events that occur to individual casualties from the point of injury, through the medical chain of evacuation, and on to long-term rehabilitative outcomes.[1] The CTR can assist medical planners and logisticians in planning for the distribution of patient condition types, the mix of health care providers, and the needed medical materials. Determination of the likely needed medical resources is required at all levels of medical care.

During OIF new advances in the medical procedures and capabilities in Navy Medicine were implemented to improve and expedite the treatment of Marines and Sailors. One such improvement was the development of the Forward Resuscitative Surgical System (FRSS), a highly mobile, rapidly deployable, trauma surgical unit capable of providing treatment for 18 patients in a 48-hour period.[2] In addition to the advances in battlefield medical treatment, body-armor technology has reduced penetrating injuries and blasts that would have been fatal in previous operations.[3]

This investigation examined the wounds incurred by US Navy–Marine Corps forces during the major combat phase of OIF from March 23 through April 30, 2003, also known as OIF-1. The goals were (1) to assess the potential impact of each agent by comparing the differences in anatomical locations, types of injuries, and the medical specialists needed to treat the casualties; (2) contrast this information with historical combat operations; and (3) identify the weapons employed against US forces.

Methods

Data were collected for Navy–Marine Corps during OIF-1, the first phase and peak involvement of Marines during OIF. All casualties who were seen at a level 3 medical treatment facility and who were involved in hostile actions or characterized as wounded in action (WIA) were identified for analyses. Not included in the study sample were patients who were identified as returned to duty (RTD), disease and non-battle injury, KIA, or died of wounds.

Data were obtained primarily from the Navy–Marine Corps CTR, which included medical information for Sailors and Marines who were seen at the Shock Trauma Platoons, FRSS, surgical companies, Fleet Hospitals, and Landstuhl Regional Medical Center (LRMC). In addition, Transportation Command Regulating and Command and Control Evacuation System data and Personnel Casualty Reports were used to validate and verify information.

Hostile action information was ascertained from medical history reports, hospitalization records, and the CTR. In addition, these data were also verified using a database maintained by the LRMC Navy Liaison Medical Officer, which documented administrative information for each Marine and Sailor who was admitted or seen at LRMC.

The LRMC hospitalization records provided the most detailed information. Data extracted included the *International Classification of Diseases, 9th Revision* (ICD-9) codes, cause of injury, and the medical provider who evaluated and treated the casualty. A typical LRMC hospital record consisted of administrative information, narrative of the incident, medical air evacuation summary, date of admission and disposition, mechanism of injury, ICD-9 diagnoses and procedures, pain management assessment, operation report, radiological examination report, and nursing, doctor, and progress notes. However, the scope of this study focused only on the diagnostic information, causative agent, and needed medical specialists.

Results

A total of 279 US Marines and Sailors were identified as WIA during OIF-1 (97% Marines and 3% Sailors). All casualties were grouped by ICD-9 subcategories, anatomical locations, causative agents, and medical provider (Tables I–IV). Tables V and VI provide more in-depth analyses of the relationship between the causative agent and the anatomical location, and ICD-9 diagnostic categories. Tables VII and VIII compare the results to historical combat operations.

ICD-9 Categories

A total of 617 diagnoses were recorded for 279 patients and grouped into their respective ICD-9 categories, as shown in Table I. The data were grouped by ICD-9 categories since hospitalization data are usually reported in this nomenclature. All diagnoses for each patient were recorded to illustrate that casualties sustained multiple injuries, which averaged 2.2 per patient. The most frequent injury category was open wounds, followed by fractures. These two diagnoses accounted for almost 60% of all injuries (Table I). This percentage has been consistent for all combat operations since World War II.[4-7]

Anatomical Locations

An average of 1.6 anatomical locations of the body were exposed to injuries (Table II). Upper and lower extremities accounted for approximately 70% of all injuries, a percentage consistent for battlefield injuries since World War II.[4-7] The widespread use of body armor has prevented penetrating thoracic and abdominal injuries; however, wounds to unprotected regions remain a major problem.[5] Closer examinations of the types of injuries, severity, and the disposition of the casualty will provide better insight into anatomical location distributions.

Causative Agent Categories

The causative agents were classified into 7 major categories: small arms, explosive munitions, motor vehicle accidents, falls, weaponry accidents, and other/unknown (Table III). The small-arms category consisted of pistols, rifles, and machine guns. The explosive munitions category consisted of improvised explosive devices (IEDs), mortars, land mines, rocket-propelled grenades (RPGs), and shrapnel. The shrapnel category accounted for cases when the causative agent was indicated as only shrapnel or fragment, which likely was the result of an RPG, IED, artillery shell, or mortar.

Surprisingly, there were a considerable percentage of motor vehicle accidents (almost 10%) and injuries resulting from falls (6%). Weaponry accidents were caused by misfires or recoiling malfunctions during hostile actions. The "Other" causative agent category included blunt trauma, crush, knife/pierce, and helicopter crashes. Explosive munitions and small arms accounted for approximately 3 out of 4 combat-related injuries.

Medical Specialists

The determination of medical specialists was obtained from the individual hospitalization charts and from LRMC administrative reports (Table IV). Due to the large number of open wounds and fractures to the extremities, 43% of casualty injuries required orthopedic specialists, making them the primary medical specialists. General surgeons were the second most needed specialists (~30%).

Anatomical Location Distributions by Small Arms and Explosive Munitions

Closer examination of small arms and explosive munitions showed considerable differences in the location of the injuries (Table V). The explosive munitions injuries were the largest producer of wounds to more than one location, with land mines the highest (3 anatomical regions

per person). The intensity of peppering and velocity of the fragments often resulted in wounds to multiple sites. RPGs and IEDs exhibited the highest percentage of injuries to the eye and the ear. Land mines caused the highest percentage of injuries to the lower extremities. IEDs and mortars were responsible for higher percentages of injuries to the face. Regardless of causative agent, the extremities are the most vulnerable and exposed areas during combat.

Wounds resulting from small arms were usually confined to one area, unlike the explosive munitions, which were more likely to expose the more vulnerable areas of the body. This is evidenced by the average number of anatomical locations for small arms at 1.1 regions per patient. However, this should not be implied that small arms are not as fatal or serious as wounds caused from explosive munitions but that they are usually not multiple in nature.

ICD-9 Percentage Distributions for Small Arms and Explosive Munitions

Closer examinations of the various traumas by small arms and explosive munitions illustrated distinctive differences in the trauma type, and the average number of diagnoses (Table VI). Wounding by small arms was the most frequent cause of injury, resulting in the highest percentage of patients with fractures (17%) and nerve injuries (4%). Shrapnel injuries caused the highest percentage of open wounds (72%). RPGs accounted for the highest percentage of patients with partial or complete blindness and hearing loss (11%), and land mines were responsible for the highest percentage of amputations (~14%).

Further analysis of the ICD-9 categories revealed that secondary diagnoses, like infections, nerve injuries, posthemorrhagic anemia, hearing loss, and visual disturbances, often constitute a significant workload for the surgeons. Approximately 20% of RPG casualties were classified in secondary ICD-9 diagnostic categories.

Historical Examination of Causative Agents of Injury

An examination of the causative agent of injuries from combat operations in World War II, Korea, Vietnam, Operation Desert Storm during the Gulf War, Somalia, and OIF-1 were compared to identify differences in weaponry used (Tables VI and VII).[4-8] Some of the most noticeable differences were the low percentage of small-arm injuries during Desert Storm (5%) and the high percentage during Somalia (55%), the high use of indirect firing (mortars and artillery shells) during the World War II (58%) and Korean (52%) operations, and the high percentage of land mines and booby traps during Vietnam (28%). Indirect firing was primarily used during Desert Storm although the individual categories percentages were not stated from the data source.

RPGs and grenades were the highest in Somalia (31%), and second highest in OIF-1 (14%). The Other category for OIF-1 was significantly higher due to the number of motor vehicle accidents. Each combat operation possesses unique characteristics, and may suggest that terrain, operation type, and troop sizes have an impact on the weaponry used during combat operations.

Anatomical Location of Wounds

The anatomical locations of wound distributions were examined for the same combat operations. The methods of data collection and reporting were not homogeneous and varied from each operation. However, an attempt was made to normalize the data by removing the multiple-wound percentage categories and readjusting the percentages to 100% (Table VIII).
The most notable difference among anatomical location distributions was that wounds to the abdomen have declined since the Gulf War. The type of wounds, the agent causing the injury, and the severity of the wound require additional analysis to determine further differences among the anatomical location distributions.

Discussion

Injured military personnel usually incur multiple, as opposed to single, battlefield injuries, and these wounds vary based on the combatants' weapons. Open wounds and fractures to the extremities account for the majority of combat injuries. However, when individual causative agents are examined, other wounding patterns become evident. Land mine injuries result in the highest percentage of amputations. RPGs cause the highest percentage of hearing loss and visual disturbances, and RPG and mortars are responsible for the highest percentage of burns. Explosive munitions account for the highest percentage of infections, due to the shrapnel and fragments that are lodged into the skin, and the highest percentage of ICD-9 diagnoses per patient, with land mines the highest at 4 diagnoses per patient. Also, they are the largest producer of multiple wounds, as evidenced by the average number of anatomical locations. Small-arms were the most used weaponry during OIF-1, generally producing wounds in centralized locations. However, such wounds were responsible for the highest percentage of nerve injuries. Motor vehicle accidents were a major concern, and more work in this area needs to be done to reduce them during all operations.

Although anatomical locations of wound distributions are fundamental data to any medical investigation of battle injuries, they must be analyzed based on the severity, type of wound, and the agent causing the injury. Due to the large number of open wounds and fractures to the extremities, orthopedic specialists were the primary medical specialists needed to treat the casualties. Colonel David W. Polly, chief of the Department of Orthopedic Surgery and Rehabilitation at the Walter Reed Army Medical Center in Washington, estimated about 80% of the wounds he and his staff have treated during OIF have been to arms and legs.[9]
Future military operations likely will take place in urban environments, making casualties more vulnerable to close-quarter combat and producing unique patterns of injury. As computer

simulation capabilities expand, it will be possible to incorporate an increasing number of factors to enhance medical forecasting accuracy for the derivation of corollary projections of the staffing demands, requisite equipment, and needed medical supplies.

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TABLE I

ICD-9 DIAGNOSES OF MARINES AND SAILORS WOUNDED IN ACTION DURING OIF-1

ICD-9 Diagnostic Categories	*N*	%
Open wounds (870-897), excludes amputations	259	42.0
Fractures (800-829)	109	17.7
All other ICD-9 codes	64	10.4
Supplemental classifications (V-codes)	28	4.5
Burns (940-949)	22	3.6
Sprains and strains (840-848)	20	3.2
Amputations (885-887) & (895-897)	15	2.4
Contusions (920-924)	15	2.4
Acute posthemorrhagic anemia (285.1)	14	2.3
Infections bacterial infection (041.XX)	12	1.9
Superficial injuries (910-919)	12	1.9
Intracranial injury (850-854)	10	1.6
Hearing loss (389.1)	9	1.5
Nerve injuries (950-957)	9	1.5
Dislocations (830-839)	8	1.3
Blindness, visual disturbances (368-369)	7	1.0
Crushing injury (925-929)	6	0.8
Total diagnoses	617	100.0
Total patients	279	
Average diagnosis per patient	2.2	

OIF-1 was the initial and major combat phase of Operation Iraqi Freedom, from 21 March through 30 April 2003.

TABLE II

ANATOMICAL LOCATIONS OF MARINES AND SAILORS WOUNDED IN ACTION DURING OIF-1

Anatomical Locations	%
Lower extremities	34.5
Upper extremities	33.9
Face	5.6
Chest	5.0
Back	4.5
Eye	4.5
Head	3.9
Ear	2.7
Neck	1.9
Pelvis	1.9
Abdomen	1.7
Total	100.0
Total anatomical areas	454
Average anatomical locations per patient	1.6

TABLE III

PRIMARY CAUSATIVE AGENT OF MARINES AND SAILORS WOUNDED IN ACTION DURING OIF-1

Causative Agent	*N*	%
Explosive munitions	130	46
Shrapnel, unspecified	40	14
RPG	39	14
IED/Blasts	20	7
Mortar	20	7
Land mine	11	4
Small arms	70	25
Motor vehicle accidents	26	9
Falls	18	6
Weaponry accidents (hostile)	10	4
Other	14	5
Not stated	11	4
Total	279	100

TABLE IV

MEDICAL SPECIALISTS REQUIRED TO TREAT MARINES AND SAILORS DURING OIF-1

Medical Specialist	*N*	%
Orthopedic	120	43
General surgery	82	29
Neurology	17	6
Hand surgery	15	5
Thoracic surgery	9	3
Ophthalmology	8	3
Vascular	5	2
Ear/Nose/Throat	5	2
Oral surgery	4	1
Podiatry	4	1
Burns	3	1
Intervertebral disk	3	1
Pulmonary	2	1
Internal medicine	1	.5
Not stated	1	.5
Total	279	100

TABLE V

ANATOMICAL LOCATIONS OF MARINES AND SAILORS WOUNDED IN ACTION BY EXPLOSIVE MUNITIONS AND SMALL ARMS DURING OIF-1

Location	IED/Blast	Land Mine	RPG	Mortar	Shrapnel	Small Arms
Abdomen	0.0%	3.0%	1.2%	3.3%	0.0%	4.9%
Back	0.0%	0.0%	2.5%	3.3%	1.7%	1.2%
Chest	2.8%	3.0%	3.7%	0.0%	5.2%	8.5%
Ear	5.6%	0.0%	9.9%	0.0%	1.7%	0.1%
Eye	8.3%	0.0%	9.9%	3.3%	5.2%	1.2%
Face	13.9%	3.0%	2.5%	10.0%	15.5%	4.9%
Neck	0.0%	0.0%	2.5%	0.0%	6.9%	1.2%
Head	5.6%	0.0%	6.2%	3.3%	5.2%	1.2%
Low extremity	30.5%	78.9%	25.9%	33.4%	29.3%	31.7%
Pelvis	2.8%	0.0%	2.4%	6.7%	1.7%	2.4%
Upper extremity	30.5%	12.1%	33.3%	36.7%	27.6%	42.7%
Total	100%	100%	100%	100%	100%	100%
Patients	20	11	39	20	40	70
Anatomical regions	39	33	81	30	58	82
Total regions per patient	2.0	3.0	2.1	1.5	1.5	1.1

TABLE VI

PERCENTAGE DISTRIBUTION OF ICD-9 CATEGORIES BY EXPLOSIVE MUNITIONS AND SMALL-ARMS FOR MARINES AND SAILORS DURING OIF-1

ICD-9 Categories	IED/Blast	Land Mine	RPG	Mortar	Shrapnel	Small Arms
Infections (041.XX)	0.0%	0.0%	4.0%	0.0%	0.0%	3.0%
Acute posthemorrhagic anemia (285.1)	3.2%	6.8%	4.0%	0.0%	0.0%	1.9%
Blindness, visual disturbances (360-379)	0.0%	0.0%	5.0%	0.0%	2.9%	0%
Hearing loss (389.1)	1.6%	0.0%	6.0%	1.6%	1.5%	0%
Fractures (800-829)	11.3%	13.6%	12.0%	6.5%	5.9%	17.1%
Dislocations (830-839)	1.6%	0.0%	0.0%	0.0%	0.0%	0%
Sprains and strains (840-848)	0.0%	0.0%	2.0%	1.6%	0.0%	1.0%
Intracranial injury (850-854)	3.2%	0.0%	2.0%	1.6%	0.0%	1.0%
Open wounds (870-897)	53.2%	43.2%	36.0%	37.1%	72.1%	52%
Amputations (885-887) & (895-897)	3.2%	13.6%	6.0%	3.2%	0.0%	0%
Superficial injuries (910-919)	4.8%	2.3%	3.0%	0.0%	1.5%	0%
Contusions (920-924)	3.2%	0.0%	2.0%	1.6%	4.4%	0%
Crushing injury (925-929)	0.0%	0.0%	0.0%	0.0%	0.0%	0%
Burns (940-949)	3.2%	0.0%	8.0%	8.1%	0.0%	0%
Nerve injuries (950-957)	0.0%	2.3%	1.0%	0.0%	1.5%	4%
All other ICD-9 codes	6.5%	13.6%	4.0%	9.7%	10.3%	11%
Supplemental classifications (V-codes)	4.8%	4.5%	5.0%	0.0%	0.0%	9%
Total	100%	100%	100%	100%	100%	100%
Patients	20	11	39	20	40	70
Total number of ICD-9 codes	62	44	100	44	68	155
Average number of ICD-9 codes per patient	3.1	4.0	2.6	2.2	1.7	2.2

ICD-9, *International Classification of Diseases, 9th Revision.*

TABLE VII

CAUSATIVE AGENT PERCENTAGE DISTRIBUTIONS FROM HISTORICAL COMBAT OPERATIONS

Arena	Small Arms	Rocket/ Bomb	Mortars/ Artillery Shells	Grenades/ RPGs	Land Mines/ Booby Traps	Shrapnel/ Unspecified	Other	Total
WWII	20	2	58	3	4	*	14	100%
Korea	27	1	53	9	4	*	8	100%
Vietnam	27	3	12	7	28	16	7	100%
Desert Storm	5	*	95*	*	*	*	*	100%
Somalia	55	0	0	31	0		14	100%
OIF	25	0	7	14	4	14	27	100%

*Desert Storm only indicated small arms and shrapnel causative agent injury categories.

TABLE VIII

WOUNDED-IN-ACTION CASUALTIES (ALL INJURIES) BY ANATOMICAL LOCATION DISTRIBUTIONS FROM SELECTED COMBAT OPERATIONS

Arena	Head & Neck	Thorax	Abdomen	Upper Extremities	Lower Extremities	Total
WWII	18	7	8	26	41	100%
Korea	17	7	7	31	38	100%
Vietnam	18	9	6	23	45	100%
Desert Storm	19	2	1	35	43	100%
Somalia	18	7	1	41	33	100%
OIF	19	9	2	34	35	100%

REPORT DOCUMENTATION PAGE

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1. Report Date (DD MM YY)
13 Sep 2004

2. Report Type
Interim

3. DATES COVERED (from - to)
1 Oct 2003 – Sep 30 2004

4. TITLE AND SUBTITLE
Wounding Patterns of United States Marines and Sailors During Operation Iraqi Freedom: Major Combat Phase

5a. Contract Number:
5b. Grant Number:
5c. Program Element: 63706N
5d. Project Number: M0095
5e. Task Number:
5f. Work Unit Number: 60332

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P.O. Box 85122
San Diego, CA 92186-5122

9 PERFORMING ORGANIZATION REPORT NUMBER
Report 05-01

8. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)
Chief, Bureau of Medicine and Surgery
Code M2
2300 E St NW
Washington DC 20372-5300

10. Sponsor/Monitor's Acronyms(s)
BuMed

11. Sponsor/Monitor's Report Number(s)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT (maximum 200 words)

This investigation examined the wounds incurred by 279 U.S. Navy–Marine personnel (97% Marines and 3% Sailors) identified as wounded in action during Operation Iraqi Freedom from March 23 through April 30, 2003. The goal was to assess the potential impact of each causative agent by comparing the differences in anatomical locations, types of injuries caused, and the medical specialists needed to treat the casualties. The overall average number of diagnoses per patient was 2.2, and the overall average number of anatomical locations was 1.6. The mechanism of injury category was classified into 7 major categories: small arms, explosive munitions, motor vehicle accidents, falls, weaponry accidents, and other/unknown. Explosive munitions and small arms accounted for approximately 3 out of 4 combat-related injuries. Upper and lower extremities accounted for approximately 70% of all injuries, a percentage consistent for battlefield injuries since World War II.

15. SUBJECT TERMS
Operation Iraqi Freedom, Marines, wounded in action, medical planning, causative agents, mechanism of injury, casualties, combat operations, casualty distributions

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	b. THIS PAGE			Commanding Officer
UNCL	UNCL	UNCL	UU	20	19b. TELEPHONE NUMBER (INCLUDING AREA CODE) COMM/DSN: (619) 553-8429